

Science
Physical Science
8th Grade
Chemical Reactions

Overview

This module will be used to teach the concept of chemical reactions to students. Embedded in this module are many *Science as Inquiry* skills that are also taught at the middle school level. Teachers will allow students to investigate the rate at which chemical reactions take place. A scenario is given, and students conduct experiments (either provided by the teacher, or of their own design) to determine the factors that affect the rates of chemical reactions. Before beginning this unit, students should know the following:

- Examples of physical and chemical properties.
- A chemical reaction is a process in which the physical and chemical properties of the original substances change as new substances with different physical and chemical properties are formed.
- A substance that enters into a chemical reaction is called a **reactant**, and a substance that is produced by a chemical reaction is called a **product**.
- Chemical reactions always involve a change in energy. Energy is either absorbed or released during a chemical reaction.
- Energy can be released/absorbed in the form of heat, light, sound, or mechanical energy.
- The ease with which an atom will form chemical bonds determines its ability to undergo chemical reactions.

Time

Depending on the length of the class period, this lesson will be completed in 3-5 class periods.

Benchmarks

PS-M-A4: Understanding that atoms and molecules are perpetually in motion

PS-M-A5: Investigating the relationships among temperature, molecular motion, phase changes, and physical properties of matter

PS-M-A7: Understanding that, during a chemical reaction in a closed system, the mass of the products is equal to that of the reactants

PS-M-A8: Discovering and recording how factors such as temperature influence chemical reactions

SI-M-A1: Identifying questions that can be used to design a scientific Investigation

SI-M-A2: Designing and conducting a scientific investigation

SI-M-A3: Using mathematics and appropriate tools and techniques to gather, analyze, and interpret data

SI-M-A4: Developing descriptions, explanations, and graphs using data

SI-M-A5: Developing models and predictions using the relationships between data and explanations

SI-M-A6: Comparing alternative explanations and predictions

SI-M-A7: Communicating scientific procedures, information, and explanations

SI-M-A8: Utilizing safety procedures during scientific investigations

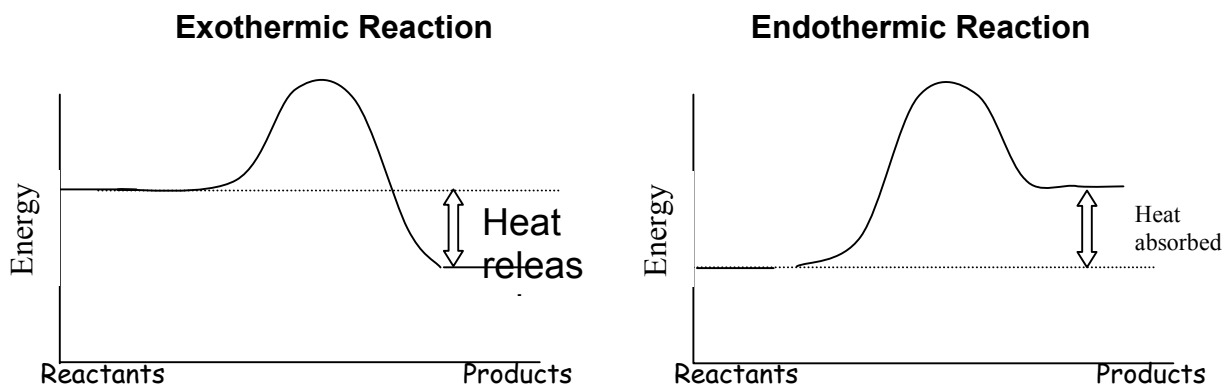
SI-M-B5: Understanding that scientific knowledge is enhanced through peer review, alternative explanations, and constructive criticism

NOTE: Not all *Louisiana Science Framework* benchmarks from the Science as Inquiry strand are addressed during the course of the presented lesson. This lesson serves as a model for the process of inquiry. With teacher modification, it is possible to address all of the above Inquiry benchmarks.

Teacher Notes

- A chemical reaction is a process in which the physical and chemical properties of the original substances change as new substances with different physical and chemical properties are formed. The substances present before the change and the substances formed by the change are the two kinds of substances involved in a chemical reaction. A substance that enters into a chemical reaction is called a **reactant**, and the substance that is produced by a chemical reaction is called a **product**.
- In order for a chemical reaction to occur, the reactants must have the ability to combine with other substances (or decompose) to form products. The ability of a substance to bond chemically with another substance is determined by the number of electrons in the outermost energy level. The bonding capacity of an atom is an important chemical property.
- Chemical reactions always involve a change in energy. Energy is either absorbed or released during a chemical reaction.
- Based on the type of energy change involved, chemical reactions are classified as either exothermic or endothermic reactions. In either type of reaction, energy is neither created nor destroyed; it merely changes location or form. A chemical reaction in which energy is released is an **exothermic reaction**. (Ex. burning or combustion) The energy content of the products is less than the energy of the reactants.

A chemical reaction in which energy is absorbed is an **endothermic reaction**. During an endothermic reaction, energy is taken into a reacting substance, usually in the form of heat or light. The energy is now stored in the molecules of the products, so the energy content is more than the energy of the reactants.



In order for the reactants to form products, the molecules of the reactants must combine to form a short-lived, high-energy, extremely unstable molecule. The energy needed to reach the peak of the "energy hill" is called **activation energy**. The atoms of the molecule are then rearranged to form products.

- In order to explain differences in reaction time, chemists must study **kinetics**. Kinetics is the study of **reaction rates**. The rate of a reaction is a measure of how quickly reactants turn into products.
- In order for a chemical reaction to occur, the particles, atoms or ions, which are reactants, must physically come into contact with one another, colliding at precisely the correct angle with the proper amount of energy. Anything that increases the frequency of these encounters will increase the rate at which products are formed.

How to Model Reaction Rates:

Reaction rates can be modeled by roping off an area of your classroom about 2 meters square. Place two students in that roped area and have them close their eyes and walk around. Every time they touch the rope, they are to yell "React!" and then turn around. Count the number of times the students collide. Gradually increase the number of students until the area is full. Have the students tell how this relates to the collision theory.

You can also model giving each group a petri dish and a cup of marbles. Have students put 7 marbles in the dish. Tell them to shake the dish and observe what happens. Model this by putting your own petri dish with 7 marbles in it on the overhead. Explain that the marbles represent the

reactants when they collide. Use the model to explain what happens throughout the debriefing.

- According to the **collision theory**, the rate of a reaction is affected by four factors: **temperature**, **surface area**, **concentration**, and **catalysts**.

Terms:

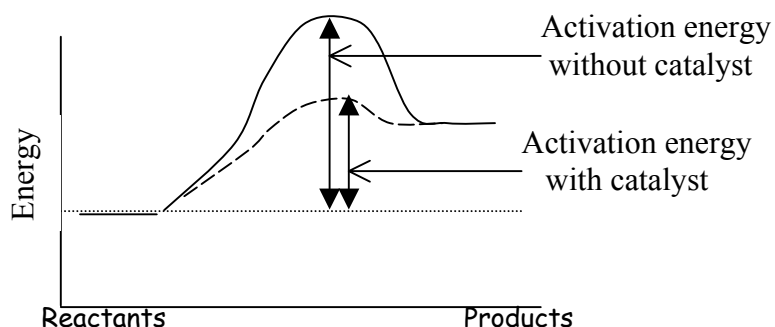
TEMPERATURE: An increase in temperature generally increases the rate of a reaction. Particles at a high temperature have more energy of motion than do particles at a low temperature. Particles at a high temperature move faster, and collide more frequently and with greater energy, thus increasing the reaction rate. More particles of reactants are able to gain the *activation energy* needed to form products. At room temperature, the rates of many chemical reactions roughly double or triple with a rise in temperature of 10°C. (Ex. Refrigeration keeps foods from spoiling; however, cooking also slows down microbial growth.) Students who investigate the effect of temperature on the effervescent tablet-water reaction should discover that as the temperature of the water increases, the reaction rate increases. Have students use the petri dish with marbles in it to demonstrate how the particles move during a reaction using cold water, room temperature water, and hot water.

SURFACE AREA: Surface area refers to how much of a material is exposed. An increase in surface area increases the collisions between reacting particles. (Ex. Many medicines are produced in the form of a fine powder or many small crystals because it is more effective than the same medicine in tablet form. Fine crystals of table salt dissolve more quickly in water than do large crystals of rock salt.) Students who investigate the effect of surface area on the effervescent tablet-water reaction should discover that as the surface area increases, the reaction rate increases. Model this by giving groups 2 more petri dishes—one with three large marbles in it and one with many BBs. Have students shake all three dishes and observe what happens.

CONCENTRATION: The concentration of a substance is a measure of the amount of that substance in a given unit of volume. A high concentration of reactants means there are a great many particles per unit volume. Since there are more particles of reactants available for collisions, more products are formed in a certain amount of time. (Ex. Blowing on a fire increases the rate of burning charcoal.) Model this by having students add marbles to the original petri dish and shaking it.

CATALYSTS: A catalyst is a substance that increases the rate of a reaction but is not itself changed by the reaction. Reactions are based on a series of steps. A catalyst changes one or more of the steps. A catalyst produces a different, lower energy path for the reaction by lowering the *activation energy*. This decrease allows more reactant particles to form products. Catalysts are

usually involved in one or more of the early steps in a reaction and then re-formed in a later step. This explains why a catalyst can be recovered at the end of the reaction. Catalysts are rare and are specific to certain reactions. (Ex. Certain automobiles contain devices called catalytic converters which speed up the reaction that changes the harmful gases produced by automobile engines into harmless ones. Enzymes in your body increase the rate of specific reactions involved in the body's metabolism.)



- Students may discover that the reaction rate increases when the effervescent tablet is placed in vinegar instead of water. They may also find out that as the ratio of vinegar to water increases in a vinegar solution, the reaction rate increases. The reactants that are present in the solution are an acid (citric acid) and a base (sodium bicarbonate). Vinegar is an acid. Since acid is one of the reactants in the chemical change, adding more reactant will increase the possibility of collision of particles and thus, speed up the reaction rate. This is only true up to a point. Once all of one reactant is used up, the reaction will stop.
- The chemicals that form acids and bases in solutions will not react in dry, solid form. In order to become acids or bases, the solid substances must be dissolved in water. This is necessary for the substances to ionize into H^+ or OH^- particles so that they can react with other substances to form new compounds. For instance, baking soda will react with vinegar because vinegar is a liquid. When the two reactants, an acid and a base, are mixed they undergo a chemical change. If baking soda and water are mixed, nothing will happen because there is no acid to react with. Baking powder, on the other hand, contains baking soda and cream of tartar. When dissolved in a water, cream of tartar is an acid, releasing H^+ ions. When baking powder is mixed with water it will react because OH^- ions are release and combine with other ions. An antacid effervescent tablet contains ingredients that, when mixed with water, will become both an acid and a base.
- Students may discover that if they decrease the amount of water too much, the reaction rate will decrease. This is because the acid particles and base particles in the tablet do not have enough liquid to ionize completely and recombine with other ions.

INFERENCE - is an assumption or conclusion based on observations. It is a reasoned guess regarding conditions, causes or consequences.

Example: Describing a glass of clear liquid as a glass of water when you do not know for a fact that it is water. It could be alcohol, vinegar, 7-Up, etc.

OBJECTIVE OBSERVATION - is a description that contains no assumptions or conclusions. It concisely describes only that which is observed. For a complete description, include what is seen, heard, smelled, and behavior. Include attributes such as color, shape, state of matter, and texture.

Materials/Equipment

INVESTIGATION 1 (per group)

- 1 generic brand effervescent tablet such as Alka Seltzer (scrape off any writing/lettering on the tablet)
- 1 clear plastic cup half-filled with water
- hand lens
- balance (optional)
- graduated cylinder (100mL)
- thermometer (C°)
- metric ruler
- stop watch
- hand lens for observations
- reproducible page for observations and inferences
- overhead projector or blackboard

INVESTIGATION 2

- Measurement/data collection tools from the first INVESTIGATION
- 5-10 Pyrex beakers
- Extra graduated cylinders
- Source of hot water (hot plate)
- Source of cold water (ice cubes)
- Extra thermometers
- Mortar and pestle (or something for grinding up the tablets)
- Assortment of different brands and generic effervescent tablets
- Clear plastic cups
- Tap water (room temperature)
- Distilled water (room temperature)
- pH paper
- Stirring rods or spoons
- Safety goggles
- Sharp knife or razor blade to cut tablets (to be handled only by teacher)
- Graph paper

Set or Opener

NOTE: The lesson is conducted in cooperative learning groups. Group members have assigned roles. (Example: Lab Leader, Recorder, Reporter, Materials Manager)

1. Pass out the reproducible page (p. 15) they will use to make observations and inferences. Review the meaning of the terms. (See teacher notes)
2. Give each group a generic brand effervescent tablet (not in the wrapper) and a clear plastic cup filled half-way with water. Do not tell students anything about either substance other than the fact that the objects are both household substances and that neither is harmful.
3. Tell groups they will have 3-5 minutes to record as many observations and inferences about the two objects that they can. Remind them to use all senses except taste.
4. Tell them that they may use any of the observation/data collection tools: a balance, a metric ruler, a graduated cylinder, a hand lens, a stopwatch and a thermometer. **Reminder:** *They are not to put the tablet in the water at this time.*
5. Call time to complete observations. Have groups report their observations about the tablet and the liquid. List on an overhead transparency. Then have them give inferences. Ask which observations contributed to each inference.

Body of the Lesson

Investigation 1

1. Have students discuss within their groups and make predictions about what would happen if they placed the tablet in the water. Have groups also discuss what observations/data collection they will make.
2. When groups are ready, give the signal to place the tablet in the liquid.
3. Have groups report their observations about the tablet and the liquid. List on overhead. Then have them give inferences. Ask which observations contributed to each inference.
4. Chances are that some group(s) will infer that a chemical reaction took place. Be sure to ask which observations or past experiences made them think so. (*Fizzing, bubbles*) "What do you think caused the fizzing and bubbling?" (*A gas was produced*) "How do you know that?" (*Previous experience*)

5. Review what happens in a chemical reaction: The physical and chemical properties of the original substances change as new substances with different physical and chemical properties are formed.

Suggested Dialogue: “Many of you inferred that the substances were effervescent tablets (like Alka-Seltzer) and water. Your inferences were correct. Can anyone tell me what the word “effervescent” means?” (*lively, excited, bubbling, fizzing*) A substance that enters into a chemical reaction is called a **reactant**, and the substance that is produced by a chemical reaction is called a **product**.” Ask students to guess what the reactants and products might be. (*The reactants are an acid and a base. The products are a salt and water and a release of carbon dioxide.*) Tell them that in this case the acid is citric acid and the base is called sodium bicarbonate. The water is used simply to help dissolve the two reactants. Actually the water behaves as a catalyst. Tell students that, **when a chemical reaction occurs in a closed system, the mass of the reactants will be equal to the mass of the products.**

6. Use **one** of the following as a springboard into the inquiry investigation:
- If only one group reports the time that it took for the tablet to disappear or if two or more groups report the same times, ask whether or not they think the times would have been the same if all groups would have timed the reaction. Regardless of the answer, ask what makes them think so.
 - If two or more groups report different times, ask what factors might have made them different.
 - If no groups recorded the time of the reaction, then ask what other observations could they have made? If necessary, mention the stopwatch. Then ask if they think every group would have recorded the same time. Regardless of the answer, ask what makes them think so.

INVESTIGATION 2

1. “The time it takes for a chemical reaction to take place is known as the **reaction rate**.” Write **reaction rate** on the board. “What are some factors that might affect the reaction rate or some things that you could do to slow down or speed up the reaction rate?”
2. List all answers without comment whether they are correct or not. (*Water temperature, particle size, concentration, brand of tablet, type of water, different liquids as solvents, quantity of reactants, agitation such as stirring or shaking, method of tablet release, etc.*)
3. NOTE: If you have access to a computer and Inspiration Software, you may want to use it along with *rapid fire* to brainstorm with students.

4. "I'm glad you came up with such a good list of possibilities because I have a job for you." Hand out the TASK, p. 16. Present the following scenario:
(See *Reproducible Pages* – p. 16)

Your company has been hired by Speedy Relief, Inc., a pharmaceutical company. In order for the company to be successful and keep its promises to the consumers, its products must work faster than products from other companies.

Unfortunately, the company is now run by a new owner who recently inherited the company from a distant cousin. He knows very little about chemicals and how they work. Your task is to investigate factors that affect the reaction rates of effervescent tablets.

Each team will choose one of the factors listed on the overhead, and design an investigation using the materials available on the table. You will have two days to conduct your investigation, gather data, and prepare a presentation for the owner.

Your presentation should include:

- Your purpose,
- Your hypothesis and a reason for your prediction,
- A brief outline of your procedure used in your investigation, including materials/equipment used,
- Organized data in charts or tables collected from your investigation,
- If appropriate, the use of graphs to display findings,
- An oral summary of your findings, and
- A conclusion and an explanation of why your group decided as it did.

5. Have groups discuss and then select a factor to test (first-come-first-serve). Check off the factors as groups make their decisions. Eventually, temperature, particle size, and concentration should be investigated. You may want to allow anything to be investigated the first round and have students do follow-up investigations until all are covered, or you may want to manipulate these particular investigations by checking off those items that you want investigated and asking groups to volunteer to investigate those certain factors. It is important to allow students to select what they want to investigate to encourage buy-in and ownership.
6. Provide students with the INVESTIGATION RECORD (pp.17-18). Depending on the experience and level of the students, you may want to guide them through the steps of an investigation beginning with writing a testable question. If you guide them through step by step, you will probably have to allow more days for the lesson. You can also allow them to make

their mistakes and use the debriefing period for discussing good investigation procedures.

TEACHER-GUIDED INVESTIGATION PROCEDURES: Use parts of or all of the following if students have little or no experience in investigative science.

1. “Scientists always begin an investigation with a testable question. Think about what you want to find out and write a testable question for your group.” Testable questions should include the manipulated, independent variable (the variable to be tested or changed) and the responding, dependent variable (what happens as a result of manipulating a variable), i.e., “How does surface area affect reaction rate?”
2. “The next step is to guess the answer to the question (predict what will happen or form a hypothesis). A hypothesis should show a relationship between the manipulated (**independent**) variable and the responding (**dependent**) variable. It is usually written in the following form: (Write on board.) As the independent (manipulated) variable increases, the dependent (responding) variable (increases, decreases, or is not affected).” Guide students by using an example (preferably one that was not selected). “Suppose your testable question was ‘*How does the volume of water affect the reaction rate of an effervescent tablet?*’ Let’s say that you fill three cups with three different amounts of water.” Sketch on the board for visual learners. “Can someone guess what might happen when you add the effervescent tablet to the liquid?” Accept any answer. Continue to ask what else could happen until students give all three possibilities:
 - As the volume of water increases, the reaction rate increases.
 - As the volume of water increases, the reaction rate decreases.
 - The volume of water does not affect the reaction rate.
3. Tell groups to discuss the possibilities of their investigation and decide which factor they would like to include in their hypothesis. If students disagree, have them compromise in order to select *one hypothesis per group*. Remind them that in science, it’s okay if the hypothesis turns out to be wrong. The whole idea is to discover the results of manipulating the independent variable.
4. Act as a facilitator to guide students in writing a procedure. Tell them that the procedure is like a recipe with step-by-step directions. If they leave out steps, it can cause the experiment to produce incorrect results. Explain how a good investigation is always repeatable, so it is important to be very clear in the procedure. They should make a list of materials on the side as they think through what they should do. You can have them choose from the materials you have provided (for Investigation 1 and 2) or you can allow them the freedom of using anything they want. Whichever you choose to do, point out that science is often enhanced or hindered by available technology. During

the development of the procedure, explain that scientists always test things more than one time. Ask why they think that would be important. Tell them that for most tests that they will conduct, they should *repeat the test at least three times*.

5. If you haven't done so before, introduce variables at this time. You can do this by giving them a scenario of an investigation and asking what is wrong with it. Example: "Suppose I'm investigating to see if the amount of water affects reaction rate. I pour 100 mL of hot water into a Pyrex beaker, 150 mL of room temperature water into a plastic cup, and 200 mL of cold water into a Styrofoam cup." Sketch this on the board for the visual learners. "Then I place a brand name antacid tablet in the hot water and an generic tablet in the other cups, and I find out that there is a difference... Would this be a good experiment? Why or why not?" (*You wouldn't know if the difference was caused by the difference in the water volume, water temperature, the type of container, or brand of tablet*)
6. "Each condition that can be changed is called a **variable**. In any scientific investigation, we can only change one variable at a time. In the experiment I described, what is the only thing that should be changed?" (*amount or volume of water*) "The variable that we change is called the **independent variable** (manipulated variable) because we 'manipulate' or change it. *All other conditions, or variables, must remain the same (or constant)*. What are some conditions that may be changed while working with effervescent tablets?" (Container type and size, amount of liquid (concentration), temperature of liquid, brand of tablets, size of pieces, etc.) "The conditions measured or observed to determine the results of altering the independent variable are called the **dependent variables** (responding variables). They are called the dependent variables because they depend on the changes that the experimenter makes in the independent variable.
7. What should the dependent variable be in every group's investigation?

(*the reaction rate increases, decreases, or doesn't change at all*)
8. "Scientists always keep careful notes about what they do. They also accurately measure changes in the dependent variables. We call these notes and measurements **data**. It's important to write down data in a neat and organized way so that other scientists can easily understand the data."
9. Demonstrate how students can create a table. Ask for suggestions for the title (which should indicate what the table is about), column headings, etc. Use the analogy of sporting events in creating titles for charts and graphs. The first part of the title is always the variable that is tested and the second part of the title is what happened as a result of the tested variable.

10. Be sure to explain the importance of indicating units of measure and that all measurements should be taken using the International System of Measurement (metric system).

Example:

Amount of Water Versus the Reaction Rate

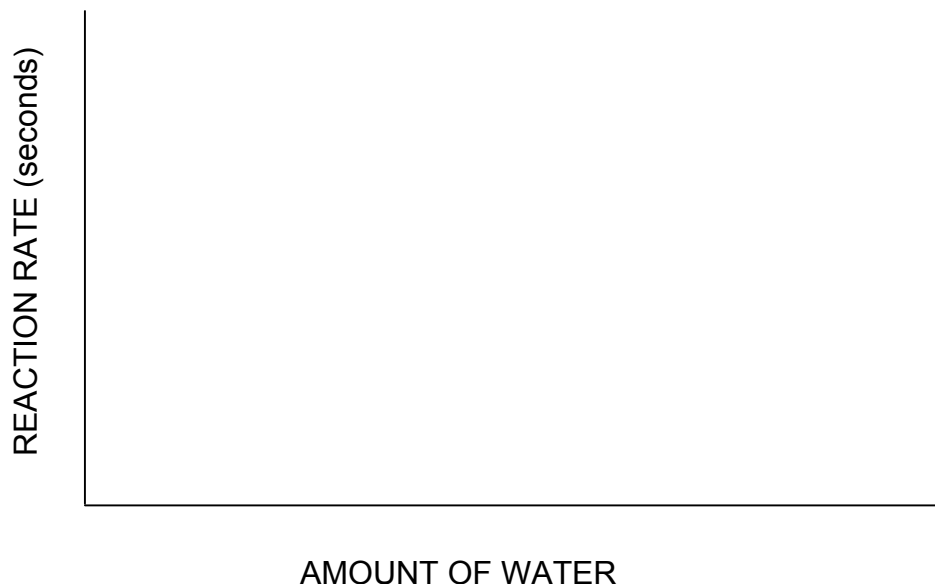
		AMOUNT OF WATER (mL)		
		100 mL	150 mL	200 mL
RATE OF REACTION (seconds)	Test 1			
	Test 2			
	Test 3			
	Average			

11. Students should decide on how they could best graphically illustrate their results. Again, you may want to model how to set up a graph.

- The **title** of the graph should be the same as the table.
- The **x axis** (horizontal) is the manipulated variable and the **y axis** (vertical) is the responding variable.

Example:

Amount of Water (mL) Versus the Reaction Rate (seconds)



Note: In some instances, it may be more appropriate to use bar graphs. For example, if a group decides to test to see if different liquids make a difference in reaction rate, a bar graph would be needed because you will be comparing the results in liquids.

12. Allow students time to develop a rough draft of their procedure, materials list, and data collection format. Instruct them to bring the draft to you for approval prior to conducting their tests. You may need to use guiding questions or suggestions to enable students to see flaw in their draft and have the opportunity to correct their draft. Do not tell them exactly what to do. If they leave a flaw following your questions and/or suggestions, that will be a learning process for them.
13. Upon approval, have students actually conduct the tests and report their findings to the class. Have them use large sheets of chart paper to present their data (charts and graphs).
14. During debriefing (follow-up discussion), encourage questions for each group from other students. Always ask, "If you were to do this over again, what would you do to make your investigation better?" Whatever you do, don't breeze through the debriefing. *This is extremely important in reinforcing concepts and process skills as well as assessing what students know and understand.

Closure

Debrief the students as to the important concepts and terms that were learned during the class period. Depending upon the length of the class, individual teachers will cover varying amounts of content in different time frames. Make sure your closure for each day debriefs content that was taught on that particular day. Important concepts to debrief are in bold throughout the body of the lesson.

Activities/data sheets/lab sheets - Attached

Observations and Inferences

OBSERVATIONS	INFERENCES



TASK

Speedy Relief, Inc., a pharmaceutical company, has hired your company. In order for the company to be successful and keep its promises to the consumers, its products must work faster than products from other companies. Unfortunately, the company is now run by a new owner who recently inherited the company from a distant cousin, and he knows very little about chemicals and how they work. Your task is to investigate factors that affect the reaction rates of effervescent tablets. Each team will choose one of the factors listed on the overhead, and design an investigation using the materials available on the table. You will have two days to conduct your investigation, gather data, and prepare a presentation for the owner.

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- A conclusion and an explanation of why your group decided as it did.

Names: _____

Date: _____

INVESTIGATION RECORD

PROBLEM: (Testable question: What do we want to find out?)

HYPOTHESIS (What do we think will happen?)

MATERIALS (What materials and equipment will be need to test our hypothesis?)

PROCEDURE (How will we set up our investigation?)

RESULTS (How will we organize our collected data? Will we use tables, charts, graphs, etc.)

ANALYSIS (What happened? How does the evidence support the hypothesis or not support the hypothesis?)

CONCLUSION (A one sentence statement. Did you prove or disprove your hypothesis?)

Have the teacher check your written procedure before beginning the actual experiment. Be sure to clean up your workspace when you are finished.

Additional Suggested Assessment Items:

Benchmark: PS-M-A8

1. When baking soda (a base) and vinegar (an acid) combine, a chemical reaction takes place. Which of these would react the fastest with baking soda?
 - A. vinegar at 12 degrees Celsius
 - B. vinegar at 15 degrees Celsius
 - C. vinegar at 18 degrees Celsius
 - D. vinegar at 25 degrees Celsius

Benchmark: PS-M-A7

2. The mass of the products in this reaction will be:
 - A. Less than the mass of the reactants
 - B. More than the mass of the reactants
 - C. Equal to the mass of the reactants
 - D. Impossible to determine
3. Using the vinegar and baking soda example in #1, name and explain two ways that you could slow down the reaction.

Assessment Key

1. D

2. C

3.

Rubric for # 3

Points

Student response

2 Possible accurate answers could include putting the vinegar in the refrigerator (decrease temperature), adding more baking soda and/or vinegar (change the concentration), or lumping the baking soda together (decrease surface area). The student answers with two correct ways to slow a reaction.

1 The student provides only one method for reducing the reaction rate.

0 The answer is incorrect or irrelevant.